EXHIBIT A

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Plumbing Noises

Identify the Problem

Several factors exacerbate water hammer and are generally traceable to inadequate system design and installation. These include:

Improperly sized supply lines for given peak water flow velocity;
Excessive system water pressure and lack of pressure-reducing apparatus;
Inadequate strapping or securing of plumbing to structure;
Excessively long straight runs with no bends;
Lack of expansion tank or other dampening system, such as water hammer arresters;

The first thing to check is the water pressure in your house. You can buy a pressure gauge for this at most hardware and home improvement stores. Attach the gauge to the cold water outlet for your washing machine. (Some water will spill out of the washing machine hose when you remove it, so hold a towel under it.) Turn off the water for anything in the house that uses water. This includes all the faucets in the house, ice makers, reverse-osmosis type water purifiers, and make sure the toilets aren't filling. Any water running in the house may cause an inaccurate reading on the gauge. Turn on the water faucet that the gauge is attached to, and then read the water pressure on the gauge. That's all there is to it!

After the test turn off the water and disconnect the gauge. (Some water will spill out of the gauge when you remove it so hold a towel under it when you remove it.) The pressure reading you get from the gauge should be 60 PSI or less. Pressures higher than 60 PSI can be the source of the noise problem. But just as important, water pressures higher than 60 PSI can cause a lot of other plumbing problems too. So if the pressure is higher than 60 PSI you need to fix that first.

If one of the parts inside the pressure reducing valve is broken, the valve may jamb closed when you try to adjust it. If this happens you will need to replace the valve immediately! To adjust the pressure on the valve you turn the bolt that protrudes from the bell shaped part of the valve (see photo below). When selecting a new pressure reducing valve make sure you get a brass-body model similar to that shown in the photo below.

Warning: installing or replacing a pressure reducing valve involves a moderate to high level of plumbing skill, you may want to hire a plumber for this if you are not experienced with plumbing.

Typically it requires cutting pipes. If the water pressure is less than 50 PSI, then the next thing to check is for loose pipes that may be bumping each other, making noise. In the case of loose pipes the sound will usually become much louder as you approach the source.

When water moves through a pipe it makes noise. Although it might seem to be a smooth flow, the water inside the pipe actually churns and tumbles as it moves through. The normal sound of water moving through pipes is a steady, even sound. The best way to know what it sounds like is to go turn the bathtub water on full blast, then go to other rooms of the house and listen. (Don't let the tub overflow!) Some newer bathtubs don't use enough water to make the pipes "sing" so you may have to turn on several faucets at the same time to create enough volume. The sound you will hear is the normal sound of water flowing through the pipes. If that is the sound you are hearing that is bothering you, then unfortunately, there is little you can easily do about it. Water makes more noise as it moves faster through the pipes. Replacing the pipes with larger pipes will reduce or even eliminate the noise you can hear. But that is a huge undertaking.

A continuous thump, thump, thump noise, consisting of evenly spaced thumps when the water is running may be caused by a under-size water meter. The noise may also be a tapping sound. The noise may appear to come from the water heater as the tank amplifies the sound. Check the water meter, you will likely hear the noise coming from it. The solution is to install a larger meter

A pipe that is changing temperature will clunk as it expands or contracts. The noise results from the pipe suddenly shifting position. This is common inside a house when hot water is turned on. The hot water flows into the cold pipes causing them to expand. But this temperature change related noise may also occur in less expected times and locations. For example a water pipe that supplies irrigation water may pass through an attic or crawl space where it may get hot on a warm day. When the irrigation comes on cold water is pulled into the pipe, causing it to contract and make noise. The key to pipe expansion/contraction related noise is that the clanking noises are not uniformly spaced, they occur randomly. The noise is generally noticeable but not loud. The noise occurs soon after water is turned on someplace and stops after a minute or two as the pipes reach the new temperature. Installing insulation on the pipes may help reduce the noise. Loosening straps that hold the pipes in place may also reduce the noise by allowing the pipe to slide easier as it expands and contracts. Often there is little you can do to completely eliminate this type of noise and it is something you will just have to live with.

Air in the pipes can cause an awful lot of noise! It can be much worse to listen to than true water hammer. The noise of air in the pipes is often a vibrating sound or a rapid ticking sound similar in pace to a machine gun firing. (At least what one sounds like in the movies.) Air in the pipes can be really difficult to get rid of. Air tends to get trapped at high points of the pipe system where it is difficult to push out. As the water moves in the pipes it breaks the pockets of air up into tiny bubbles. Then the water flows past the bubbles, leaving the air still in the pipe. These tiny bubbles moving around, and expanding and contracting, are that rapid vibrating sound you hear. (Everyone who has been to Hawaii knows how annoying the sound of Tiny Bubbles can become after a few repetitions.)

Water hammer can also be the source of the noise. Water hammer can be a big thump that shakes the house, or a series of banging noises starting with a loud bang followed by several "echoes". The best way to identify if the noise is water hammer is to ask yourself "when does it happen?" If the noise occurs when you open a valve or a faucet, it is probably air in the pipes. If it occurs when a valve closes or the washer changes cycles, it is probably water hammer. If it occurs when a pump starts, it could be water hammer, air in the pipes, or both. Although opening valves can sometimes create water hammer, this typically only occurs with valves larger than 3" in size, and even then it is reasonably rare.

So here's your noisy pipe checklist:

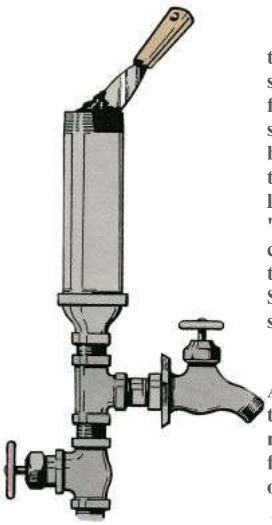
- Noise when a valve closes = water hammer.
- Noise unrelated to valve opening or closing = air in pipes or loose pipes moving around and striking objects.
- Noise when a pump starts = water hammer and/or air in pipes.
- Loud single thumps or multiple quick bumps, then no noise. This tends to be water hammer.
- Vibrating and prolonged noises tend to be air in the pipes.
- A continuous, uniformly spaced tap, tap, tap noise when water is running may be caused by an under-size water meter.

Air in the Pipes

There are only two ways I know of to get the air out; push it out by increasing the water velocity (speed), or open the pipe and release the air.

To push the air out you need to temporarily increase the water velocity to the point the water "sweeps" out the air bubbles. To increase the velocity you need to turn on as many water outlets as possible. That creates a high water demand and the water velocity goes way up. As the water rushes through the pipe the trapped air is swept along with it and out of the pipe.

If the air is in the irrigation mainline (a mainline is the pipe upstream of the circuit control valves) you should be able to increase the velocity by manually opening two or more of the circuit valves at once. Most electric irrigation valves can be manually opened by twisting a lever under the valve's solenoid (the thing the wires go into), or by partially unscrewing a bleed screw on top of the valve. Do not remove the bleed screw, just slowly turn it until the valve opens. Open all of the valves at the same time if you need to. Let the water run for a while to give it a chance to push all the air out. When you close the valves close them one at a time. Closing them all at once can cause a pressure surge that can damage your irrigation system. Don't be surprised if the valves take a long time to close, this is fairly normal when more than one valve is opened at the same time. If the electric valves won't close, slowly turn off the main water supply to the irrigation system, wait one minute, then slowly turn it back on. They should now be closed.



If the noise only occurs when an individual sprinkler valve (always the same valve) is opened the air may be in the lateral pipe (the pipe downstream of the valve.) In that case you will need to temporarily remove some of the sprinkler heads on that valve circuit in order to increase the water velocity. Remove the 3 sprinkler heads furthest from the valve and then open the valve to flush out the air. If that doesn't get it out try removing more sprinklers. After the air is flushed out, put the sprinkler heads back on. If that fixes the problem temporarily but it returns after the next time you irrigate, then the problem is that the water is draining out of the pipes through the sprinkler heads after each irrigation. This is probably because one or more sprinkler heads are lower than the others. When the water drains out, air gets back into the pipes. To prevent this you need to install "anti-drain check valves" at the inlet of each sprinkler head. The anti-drain check valve is a small spring-loaded check valve. The check valve holds back the water so it doesn't drain out. It does not effect the performance of the sprinkler head noticeably. Many sprinkler heads are available with this feature built-in to the sprinkler. Some brands also have retrofit kits available that allow the check valves to be easily installed in existing sprinklers. The built-in anti-drain check valves do not effect the performance of the sprinkler at all.

If the air is in your household pipes try turning on all the faucets in the house and then flush all the toilets. Again, give it a few minutes to push that air out. If you know where the water supply comes into your house turn off the faucets starting with the one closest to the water supply entry point, then close them one at a time moving away from the entry point. As you come to a toilet when you are moving through the house turning off faucets, flush it again, then wait two minutes before closing the next faucet. Don't forget the faucets on the outside of the house!
An air chamber will not drain properly if it is clogged. Remove its cap and ream out the accumulated scale inside the chamber

If the above procedures didn't get the air out...
Next try a water hammer arrestor. This often doesn't work with air problems, but it's worth a try. At your local hardware or home store look for a pre-packaged water hammer arrestor that attaches to a standard washing machine cold-water outlet. The ones I have seen come in one of those clear plastic display packages, and look like a copper tube with hose connections. Check the return policy of the store before you buy it, if you can, buy it someplace where they will take it back if it doesn't work. Make sure you keep all the packaging. Install it per the directions on the package. If it doesn't work, remove it and return it.

If the air can't be pushed out, and the water hammer arrestor didn't work, you will need to find where the air is trapped in the pipe and "open the pipe" to release it. Air rises above water, so the air is likely trapped in a high spot in the piping. Try to visualize how your irrigation system is laid out. Are there any obvious high points where air might be trapped? If you can identify a likely high point turn off the main water shut-off valve and open a faucet or valve to release the water pressure. Then cut the pipe at the high point and install a tee on it with a small valve on the tee outlet. A compression type tee may be easier to install. A 1/2" valve, or even a smaller one if you can find one, will work fine for the valve. Do not use a gate valve! Gate valves tend to leak easily. Ball valves work good. . The valve needs to be on a short nipple, a few inches above the pipe. (In the irrigation business a nipple is the name of a short length of pipe.) Close the faucet and turn the water back on. The air will rise to the highest point which is the short upright nipple under the valve. You can then open the valve just a little bit to let the air escape. Some water is going to come out too, so be prepared for it to squirt! After releasing the air put a plug in the outlet of the valve for safety.

Sometimes you will get all the air out and everything will be fine for a while, then without warning, the air noise will return. This is because the water coming into your house or irrigation system sometimes has air trapped in it. Have you ever filled a glass of water from the kitchen faucet and noticed it was a milky white color? But after sitting for a while it turns clear. That white color most likely was caused by tiny bubbles of air in the water (at least I hope it was!) This air can get in the water lots of ways, it is fairly normal and doesn't by itself mean your water is polluted or not drinkable. But this air does tend to rise out of the water when the water is sitting in your pipes, and it can form an air pocket in the pipe after a while. This causes the wonderful air noise you enjoy so much to return. If this happens often you can add a "continuous venting" type air vent in place of the valve in the drawing above. The air vent needs to be the type that releases air while under pressure. The type of air vents that are made for most irrigation systems will not work. The type you want has a float connected to an arm that uses a lever to open and close a small valve that allows the air to escape. The correct vent type is often called an "air eliminator" or "air relief valve." Look for that term "continuous venting". Most plumbing supply stores will have one. A 1/4" size one should work fine.

Water Hammer

True water hammer is essentially the sound of a "water wreck" occurring. It happens when moving water suddenly changes speed. Water hammer can be caused by a pump starting or a valve rapidly opening, however in the vast majority of cases it results when a valve closes.

and washing machines use the same type of valves as irrigation systems, you will sometimes get water hammer when the dishwasher or washing machine fill valve closes. So for this tutorial I am going to focus on water hammer caused by closing valves. Even though these so-called "electric valves" appear to be powered by electricity, they actually use water pressure as their major power source. The electric solenoid on the valve operates a tiny "pilot valve". The water flow from this tiny valve is then used to open and close the bigger valve using hydraulic pressure. This works well, but leaves a minor engineering problem. It is very hard to get these valves to close slowly! Engineers have made some great progress but they still haven't fully defeated what I call the 80/20 problem. The 80/20 problem is that valves close slowly until they are about 80% closed, then they tend to snap fully closed in a millisecond! This causes the water in the pipes to suddenly stop moving. Now we all know the story of Jack and Jill, and the reason Jack fell down is that water is heavy (and perhaps Jack was paying too much attention to Jill , and not enough to his bucket, but I'm getting off-track here.)

A column of water moving through the pipe at 7 feet per second carries with it a tremendous amount of weight and momentum. While it's not a perfect example, the one commonly used is to think of the water in the pipe as a big freight train going through a long tunnel. The valve closing is like blocking the end of the tunnel with thousands of tons of rock. When the train slams into the blocked end of the tunnel there is going to be one horrific crash! The faster that train is moving, the worse the crash will be. Thus the problem with water velocity in the pipe. The faster the water is moving, the worse the crash is going to be when the valve closes. That crash is the cause of a big thumping noise when the valve closes. Secondary thumps that follow are essentially "echoes" in the pipe.

Now that thumping sound would be bad enough, but a unique property of water makes the problem much worse than just an annoying noise. Water is essentially non-compressible (it compresses a little bit, but not much.) So all the energy it carries with it when it slams into the closed valve has to go someplace. So the energy creates a brief, but enormous, spike it the water pressure in the pipes. This spike can easily double or triple the water pressure in your system. The pressure spike occurs so fast that a standard pressure gauge will not even register it. But this increased water pressure doesn't just hang around the vicinity of the valve. It passes as a shock wave back through the pipe at (almost) the speed of sound in water, seeking a way out. This creates stress on the pipe, and if there is a weak point in the piping the pressure surge will find it. So each time the water hammer occurs it is putting stress on the pipe, which weakens the pipe. If you hear the noise in your house, then the pipe in the house is being damaged, even if the source of the surge is someplace else. It shock wave travels through the water in the pipe. So what kind of damage does it do?

Consider a standard rubber balloon. You blow up the balloon then let the air out. You do this again and again. Each time the balloon gets stretched a little more and weakens. After being blown up many times the balloon simply bursts. You didn't blow any more air into it than before, it just was weakened by the constant expanding and contracting. The pipes in your home and irrigation system stress in a similar manner when exposed to these pressure spikes. Where is the most likely weak spot where it will break? In my experience the first pipe to go is in the house, not the sprinkler system. It is often the tube connecting a toilet or sink to the household water system, which is usually a hose or thin wall pipe. The result is a flooded bathroom. If you made an error in installing the irrigation system and forgot a clamp or didn't get a good strong glue joint you may see a leak there. A small pinhole leak in plastic irrigation pipe or hose very quickly enlarges to the diameter of a pencil. Points where the pipe changes direction also take a beating as the pressure surge wants to continue in a straight line rather than go around the bend. There is one last frustrating problem with water hammer, which is that the sound you hear often appears to be coming from someplace other than the point where the water hammer was created. This is because sound travels very well through the pipe and the water in it. So you can't rely on your ears to find the source of the water hammer.

Water hammer is influenced by three variables, understanding these variables will help you find the source of your water hammer problem.

The first variable is the length of the pipe the water is traveling through. We can't do much about the length of your pipes, assuming that you can't move your house closer to the water source. But it is an important factor in creating water hammer, so it is useful to take a look at it, especially as it relates to the pipe size. For example, in some situations you can force a high rate of flow through a small pipe without problems, provided the length of the pipe is short, say, a few feet. The shorter the pipe, the smaller it can be. Knowing this will help you when you try to identify the source of the water hammer. So keep in mind that a small pipe may not be a problem if it is a very short length.

The second variable is time, or specifically how fast the water is being stopped. When a closing valve is causing water hammer, time is how long it takes for the valve to close. Most irrigation valves take several seconds to close. Theoretically this would not cause a problem, as several seconds is very slow when dealing with water hammer. The problem is that 80/20 ratio I mentioned previously. The valve may take a few seconds to go from full open to full closed, but it has a tendency to snap closed when it gets down to that last 20%. Realistically the actual closing time of a typical irrigation solenoid valve is around 1/2 to 1 second as best I can tell. But it varies greatly, even when testing the same valve. For example, an irrigation valve closes much faster if there is higher water pressure present. It also closes faster as you increase the flow through the valve (increasing the flow creates a greater pressure differential across the valve, which causes it to close faster.) So a valve that would not cause a water hammer problem at a low flow and low pressure, will cause all kinds of problems if you increase the flow through the valve and/or the water pressure.

The third factor that influences water hammer is the velocity of the water. The faster the water is traveling in the pipe, the greater the water hammer. It is this last factor which is easiest for us to correct in a sprinkler system, so most of the suggested solutions for water hammer will be aimed at reducing the water velocity.

Be aware that there are many "quick fix" devices that are supposed to fix water hammer problems for you. My experience has been that air vents, air traps, and water hammer arresters seldom work with automatic irrigation systems. Irrigation systems, particularly sprinkler systems, tend to have much more severe water hammer problems than that found in household plumbing. These devices are made to stop water hammer that is caused by household uses and they will often cure the problem in those cases. But I have never seen one fix water hammer caused by an automatic sprinkler system.

Now you need to do some detective work. Take the time to do some research. Listen for the water hammer noise. What's happening when, and especially just prior to, the time when the sound occurs? Water hammer is set off by something, it doesn't just occur randomly. Chances are a irrigation valve closes when the sound occurs. Closing irrigation valves are the source most of the time. Another frequent cause is the fill valve on a dishwasher or washing machine closing. Once you know what happens, you can focus in on it as the potential source of the problem

Solutions for Water Hammer Caused by Washing Machines and Dishwashers:

by closing it half way. If that doesn't get rid of the noise close it a little more, keep repeating until the noise stops. Closing the valve reduces the flow to the appliance, and thus reduces the velocity in the pipes. Unfortunately many dishwashers and washing machines use a fill timer rather than actually measuring if the washer is full. Sometimes when you close the valve partially the washer doesn't get enough water and the clothes or dishes don't get clean. So check to see if closing the valve is creating cleaning problems. If it is, reopen the valve a little and try again.

- There should be a short tube that leads from the shutoff valve to a appliance. Often this tube is a piece of 1/2" hose or a 3/8" copper tube. This tube should not be more than three or four feet long, if it is longer the tube may be part of the problem, so try replacing it with a larger tube.
- The next trick to try is installing a AA-size water hammer arrester on the pipe at the shut-off valve. While these devices are seldom useful for irrigation systems, they often do work with appliances because the water demand is not nearly as high as a sprinkler system. You can get a water hammer arrester at just about any plumbing supply store. At your local hardware or home store look for a pre-packaged water hammer arrestor that attaches to a standard washing machine cold water outlet. The ones I have seen come in one of those clear plastic display packages, and look like a copper tube with hose connections. Check the return policy of the store before you buy it, will they take it back if it doesn't work? Make sure you keep all the packaging. Install it per the directions on the package. If you are installing it on a dishwasher fill, you will probably need some adapters to make it fit. If it doesn't work, remove it and return it.
- Air chambers are pretty much worthless, none of the building codes recognize them any more for water hammer control. An air chamber is just a long section of vertical tube with a cap on the top of it. The idea is that air is trapped in the tube and absorbs the water hammer shock. They may work for a while, but they become water-logged with time. They also need to be huge, generally at least 3/4" size and several feet long.. So if someone suggests one, I recommend not wasting your time and money.
- The last option is to tear out the walls or floors and install a new, larger pipe to the appliance. Before you do that run a test. Get a 3/4" heavy duty garden hose. It will cost a lot, but at least you can reuse it in the garden. Hook up one end to the flush outlet on your water heater, and connect your appliance to the other end. Then run the appliance, the water hammer should be gone. If the water hammer is still there, then the pipe in the wall is not the problem.

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